Attorney Docket No.: N1085-00184 [TSMC2002-1327]

What is claimed is:

1. A method of forming a copper diffusion barrier on top surface of a low-k interlayer dielectric layer in a semiconductor device, the method comprising:

forming at least two copper interconnect structures within the low-k interlayer dielectric layer;

treating the top surface of the low-k interlayer dielectric layer to transform a thin surface layer of the low-k interlayer dielectric layer into a copper diffusion barrier.

- 2. The method according to claim 1, wherein the step of treating the top surface of the low-k interlayer dielectric layer includes plasma surface treatment in which the top surface of the low-k interlayer dielectric layer is bombarded by nitrogen atoms from the plasma formed from at least one nitrogen-containing gas, wherein the copper diffusion barrier is a layer of silicon nitride.
- 3. The method according to claim 2, wherein the at least one nitrogen-containing gas is nitrogen gas.
- 4. The method according to claim 2, wherein the at least one nitrogen-containing gas is ammonia gas.
- 5. The method according to claim 2, wherein the layer of silicon nitride is less than 100 angstroms thick.
- 6. The method according to claim 2, wherein the layer of silicon nitride is less than 50 angstroms thick.
- 7. The method according to claim 1, wherein the step of treating the top surface of the low-k interlayer dielectric layer includes plasma surface treatment in which the top surface of the low-k

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interlayer dielectric layer is bombarded by carbon atoms from the plasma formed from at least one carbon-containing gas, wherein the copper diffusion barrier is a layer of silicon carbide.

- 8. The method according to claim 7, wherein the at least one carbon-containing gas is carbon-dioxide.
- 9. The method according to claim 7, wherein the layer of silicon carbide is less than 100 angstroms thick.
- 10. The method according to claim 7, wherein the layer of silicon carbide is less than 50 angstroms thick.
- 11. The method according to claim 1, wherein the step of treating the top surface of the low-k interlayer dielectric layer includes ion implantation using at least one nitrogen-containing gas, wherein the copper diffusion barrier is a layer of silicon nitride.
- 12. The method according to claim 11, wherein the at least one nitrogen-containing gas is nitrogen gas.
- 13. The method according to claim 11, wherein the at least one nitrogen-containing gas is ammonia gas.
- 14. The method according to claim 11, wherein the layer of silicon nitride is less than 100 angstroms thick.
- 15. The method according to claim 11, wherein the layer of silicon nitride is less than 50 angstroms thick.
- 16. The method according to claim 1, wherein the step of treating the top surface of the low-k interlayer dielectric layer includes ion implantation using at least one carbon-containing gas, wherein the copper diffusion barrier is a layer of silicon carbide.

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17. The method according to claim 16, wherein the at least one carbon-containing gas is carbon-dioxide.

- 18. The method according to claim 16, wherein the layer of silicon carbide is less than 100 angstroms thick.
- 19. The method according to claim 16, wherein the layer of silicon carbide is less than 50 angstroms thick.
- 20. The method according to claim 1, wherein the low-k interlayer dielectric layer is of a silicon based organic-inorganic hybrid material.
- 21. The method according to claim 20, wherein the silicon based organic-inorganic hybrid material is one of hydrogen silsesquioxane and methyl silsesquioxane;
- 22. The method according to claim 1, wherein the copper interconnection structure is a dual damascene structure.
- 23. The method according to claim 1, wherein the copper interconnection structure is a single damascene structure.
- 24. The method according to claim 1, wherein the low-k interlayer dielectric layer is of a polymeric dielectric.
- 25. The method according to claim 24, wherein the step of treating the top surface of the low-k interlayer dielectric layer includes depositing a thin layer of material containing silicon and nitrogen by vaporization; and curing the deposited silicon and nitrogen containing layer to form the copper diffusion barrier of silicon nitride.
- 26. The method according to claim 24, wherein the step of treating the top surface of the low-k interlayer dielectric layer includes applying at least one chemical that contains silicon and

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nitrogen; and facilitating silicon and nitrogen to form a thin layer of silicon nitride on the surface of the low-k interlayer dielectric through chemical reaction.

- 27. The method according to claim 26, wherein the step of facilitating silicon and nitrogen to form a thin layer of silicon nitride includes elevating the temperature of the copper damascene structure to about 50 to 100 deg. Celsius.
- 28. The method according to claim 24, wherein the step of treating the exposed surface of the low-k interlayer dielectric layer includes depositing a thin layer of material containing silicon and carbon by vaporization; and curing the deposited silicon and carbon containing layer to form the copper diffusion barrier of silicon carbide.
- 29. The method according to claim 24, wherein the step of treating the top surface of the low-k interlayer dielectric layer includes applying at least one chemical that contains silicon and carbon; and facilitating silicon and carbon to form a thin layer of silicon carbide on the surface of the low-k interlayer dielectric through chemical reaction.
- 30. The method according to claim 29, wherein the step of facilitating silicon and carbon to form a thin layer of silicon carbide includes elevating the temperature of the copper damascene structure to about 50 to 100 deg. Celsius.
- A copper damascene structure in a semiconductor device comprising:
 a low-k interlayer dielectric layer having a top surface;
 at least two copper interconnect structures within the low-k interlayer dielectric layer;

a thin layer of copper diffusion barrier formed on the top surface of the low-k interlayer dielectric between the at least two copper interconnect structures to prevent copper diffusion between the copper interconnect structures along the top surface of the low-k interlayer dielectric layer.

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32. The copper damascene structure of claim 31, wherein the copper diffusion barrier is a thin layer of silicon nitride.

- 33. The copper damascene structure of claim 32, wherein the thin layer of silicon nitride is less than 100 angstroms thick.
- 34. The copper damascene structure of claim 32, wherein the thin layer of silicon nitride is less than 50 angstroms thick.
- 35. The copper damascene structure of claim 31, wherein the copper diffusion barrier is a thin layer of silicon carbide.
- 36. The copper damascene structure of claim 35, wherein the thin layer of silicon carbide is less than 50 angstroms thick.
- 37. The copper damascene structure of claim 31, wherein the copper interconnect structure is a dual damascene structure.
- 38. The copper damascene structure of claim 31, wherein the copper interconnect structure is a single damascene structure.

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